HISTORY OF MEDICINE

In what ways can human skeletal remains be used to understand health and disease from the past?

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Disease and illness in previous generations can be investigated using palaeopathology. This article describes the commonly used techniques in palaeopathology, includes examples of how such techniques are able to formulate data on a variety of health issues that occurred in the past and suggests how these data can be relevant today.

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Illness and injury have been a constant problem for humans. Evidence of these problems can be found in art, literature and human remains, but it is human remains that have regularly provided the scholars of ancient diseases and health with a vast amount of information. This is because art and literature are limited by linguistic and pictorial interpretation as well as by biases created by subjective description and depiction by ancient authors and artists.[1] However, the improvements in diagnostic procedures in medicine and pathology over the last 150 years have contributed to the interpretation of human remains. Accordingly, the palaeopathologist in the 21st century is able to investigate and make scientific deductions on human remains regardless of whether they are buried or cremated, bone or soft tissue. A general description of the procedures used and their main advantages and disadvantages will be given below and will focus particularly on macroscopy and microscopy, autopsy, imaging and biochemical methods.

MACROSCOPY AND MICROSCOPY

Direct evidence for pathologies and former treatments can be obtained from macroscopic examination of human remains. Skeletal and dental records are very useful for this purpose as bone is susceptible to various stresses during its lifecycle that can alter its shape, size, consistency and development. Consequently, observation of human remains together with medical knowledge enables the observer to diagnose acute and chronic lesions that were shaped by genetic, infectious, neoplastic, joint, traumatic or metabolic processes. However, pseudopathology (when external conditions such as pressure, temperature and flora and fauna after death cause effects similar to those caused by disease before death) must be taken into consideration.[2] Importantly, the examination of human remains also yields valuable information regarding ancient medical and surgical attempts at treatment. For example, observation of human remains and the objects on or around them, shows that many people from different cultures and periods had amputations, splinting of fractures, trephination of the skull and stitches, all presumably forms of medical treatment.

A macroscopic diagnosis can also be made from supposedly unhelpful remains which have in fact provided a lot of information, for example the Cro-Magnon men at Padina and Hajducka Vodenica in the Djerdap gorge, whose well-preserved remains appeared to be entirely normal other than slight ridges and bony excrescences on their jaws.[3] These finding were presumed to be insignificant until palaeobotanical research established that they were probably caused by protracted chewing of grass and plants in order to sustain a diet lacking in meat.[3] In the same way, observing that the condition of skeletal remains makes a macroscopic diagnosis impossible can still be of medical interest by suggesting insufficient vitamin D, parathyroid abnormalities and fluorine exposure.[3] Obviously, the lack of any signs in a well-preserved set of remains may not mean absence of ill health, as the individual may have had an accident or died of an acute illness.[4]

Macroscopy can be also used in palaeodemography because human remains also offer information on gender, age, ethnicity and population numbers. As males and females in early ethnic groups worked, lived and ate differently in many cultures, attention is gradually concentrating upon gender and ethnic differences in palaeopathological material in the hope of discovering aetiologies for diseases that are still common today. Also, the age of remains is repeatedly used to establish the percentage of children, youths, mature adults and old people found in burial sites.[3] These numbers are used to calculate infant mortality rates and average life expectancy, which are markers of social affluence and health in distinct ancient societies.

The microscope can reveal the influence on ancient civilisations of diseases both similar to and different from those seen today. Microscopy applied to mummies has revealed that atherosclerosis is not a recent phenomenon[5] and that parasites have infected humans in many countries for centuries as, for example, both eggs of *Trichuris trichiura* and cysts of *Entamoeba* were seen in the digestive tract of a 3500-year-old ice-preserved Chilean boy. Common conditions have been also discovered, but so has a hitherto unknown type of louse, now known as *Pediculus humanis americanus*, in the hair of an ancient Peruvian mummy.[3] Evidence has therefore been obtained of a disease-transmitting vector that, for any number of explanations, has become extinct.

The arrival of the scanning electron microscope (SEM) in 1965 has proved useful in revealing the detailed structure of human relics. It is used to identify blood cells, large organic molecules and pieces of chromosomal matter that can be genetically examined for evidence of pathogens which are known to inhibit or attack such structures. Therefore, information about the prevalence and spread of diseases in the ancient world, such as malaria, can now be obtained scientifically. However, the best known application of the SEM to date has been in surveying the connective fibres of ossein and collagen. As these fibres degrade over time, it is possible to determine whether isolated human bones are all from the same person. This was very important when it was discovered that the jawbone and cranium of the infamous Piltdown Man were of totally different ages and that the perpetrator had merely combined the jaw of an ape with a human cranium. Fortunately, therefore, one of the greatest scientific hoaxes of all time did not lead to years of error-strewn conclusions in both archaeological and palaeopathological fields.

UNWRAPPING AND AUTOPSY

Before the advent of modern technology the only way to investigate ancient soft tissues was to unwrap a mummy and carry out an autopsy, particularly in the 19th century when a mummy was the fashionable souvenir for travellers visiting Egypt. On returning to Europe, the proud owner would often unroll his prized possession as a part of a social event.[1] This was a destructive and irreversible procedure and usually neither the information obtained during this unwrapping nor the body itself was retained. However, the decision by Augustus Bozzi Granville (1783–1872) to ''sacrifice a most complete specimen of the Egyptian art of embalming in hopes of eliciting some new facts illustrative of so curious and interesting a subject''[1] was the first exception to the wasteful gatherings. It led William Osburn, Thomas Pettigrew (1791–1865) and Sir Grafton Elliot Smith (1871–1937) to produce a collection of data on the range of diseases, health beliefs and mummification techniques of the ancient Egyptian period. Many Egyptologists today feel it unnecessary to unwrap any more mummies for their numbers are limited (although material from poorly conserved mummies and those that are unsuitable for display could be used).[1] Therefore, this procedure is now commonly performed on human remains from other countries, particularly from the Pacific region where cultural disregard for the dead after one or two generations allows access to much unspoiled material.[6] Admittedly, however, this material is a lot younger than that from Egypt and may not provoke the same level of excitement among the public or in the scientific world.

IMAGING

Human remains can reveal much data when examined by the non-destructive method of radiography. This was first realised in 1898 by Sir William Matthew Flinders Petrie (1853–1942), the father of British Egyptology, yet the cumbersome and expensive equipment limited the potential of radiography until the 1960s.[1] Since then many studies have used radiography rather than macroscopy to determine the full extent of skeletal conditions such as fractures, osteoarthritis and dental problems. Moreover, radiographs can reveal internal calcification in arteries in addition to diseases of the hepatobiliary system and have previously revealed the ova of *Schistosoma (Bilharzia) haematobium* in the kidneys of mummies from the second dynasty.[7] Furthermore, radiographs can determine the gender, age, familial relationships and contents of a mummy. This allows the detection, before unwrapping, of the fake mummies constructed in response to the high demand for mummies over the last two centuries,[1] thus saving time and money.

Significantly, radiographs can detect Harris lines which are produced in bone when the body undergoes a stressful period. Merely by quantifying the lines between the diaphysis and epiphysis of long bones it is possible to estimate the dietary deficiencies and childhood diseases of ancient populations.[5] Likewise, the number of childbirths per female adult and birth rates of ancient populations can be relatively accurately calculated from the appearance of Harris lines in the female pubic symphysis. This information is meaningful to palaeo-epidemiologists who combine it with annual death rate estimates to calculate population numbers. Consequently, research on the Mycenaean era has revealed that the plague of Athens (430–427 BC), the first known catastrophic epidemic in the West, broke out just at the time and place of the greatest human concentration in Greece.[5] An interesting historical lesson for modern day public health physicians has, therefore, been produced from this palaeopathological analysing technique.

In more recent years radiographs have been used in the technique of xeroradiography, which delineates the edges of images in order to make shapes easier to see, thus providing greater diagnostic accuracy. For instance, previously the methodological problems of radiographs depicting a three-dimensional object in a two-dimensional plane and structures superimposed on each other, resulted in the belief that the profusio acetabuli in the pelvis of an Egyptian mummy (ROM I) originated from rickets or osteomalacia. However, the observation of a cartilage space by xeroradiographs has shown the source to be post mortem bending of an unfused Y-cartilage.[6] In this way important interpretative errors have been reduced in palaeopathological work.

One of the most effective tools available to the palaeopathologist is computer assisted tomography (CT). Developed in 1974, a large series of *x* rays are taken around a single axis of rotation in order to record a body in detail.[1] CT scans have all the advantages of conventional radiographs but none of the problem of superimposition as they produce separate slices of the body that can combined to produce a three-dimensional picture. In palaeopathology this highly accurate technique has enabled embalming techniques,[8] anthropometric measurements and the condition of bones and soft tissue to be recorded in minute detail.[9] It has, for example, allowed diagnosis of Schmorl's nodes, which are seen when the articular surfaces of the vertebral bodies herniate, in the 22nd dynasty priestess Tjentmutengebtiu, who was therefore likely to have carried heavy weights during her lifetime.[10] Furthermore, it is important to note that this technique can be used to examine material in the same environment in which it was found. This virtual unwrapping has been especially useful in the examination of mummified corpses found in ice, which can be damaged if subjected to the repeated partial thawing that other techniques require.[11] Similarly, CT scanners can be used to scan a coffin to compare the mummified contents with the inscriptions on the coffin, a process which again can prevent damage to human remains or, perhaps as important, to the surrounding archaeological artefacts.[12]

Technological advances have also seen the application of CT-guided biopsy in palaeopathological examinations, where an area of just 1 cm^3 can be targeted, thus destroying less surrounding tissue than conventional needle core biopsy.[13] Also material that is neither radio dense nor fluid containing can be visualised, which can be a problem in the other modern imaging methods of fluoroscopy and sonography, respectively.[13] CT-guided biopsy has enabled the diagnosis of spinal tuberculosis in an ancient Egyptian child mummy to be altered to post mortem disintegration of the thoraco-lumbar junction and is, therefore, likely to be of increasing importance in establishing the accuracy of previous research.[13]

The final imaging method to discuss is endoscopy. Although developed for industrial purposes to examine inaccessible plane parts, it is proving useful in reaching internal regions of the body. Continuous live pictures can be acquired following the insertion of a narrow tube containing a camera through a small hole or incision. Consequently, palaeopathologists have observed the mucosa of the 5300-year-old Innsbruck Iceman by inserting an endoscope through the maxillary sinus, nasal cavity and larynx and have taken histological samples from various internal sites.[14] A famous instance of its application was to show a hydatid cyst in the brain of the Manchester Man (No. 22940).[1] This infection is caused by the consumption of tapeworm infested food and therefore throws light on ancient domestic practice and hygiene and suggests the probable symptoms that the individual suffered towards the end of his life. However, a high level of operative skill is required for endoscopy and it is presumed to be more destructive than CT-guided biopsy.

BIOCHEMICAL ANALYSIS

Medical laboratories are providing the palaeopathologist with tests that can examine at the cellular and molecular level. Some of these routine chemical and toxicological tests have been used to examine, for example, lead poisoning in ancient potters and the composition ancient gallstones. They were also crucial in the discovery that Lindow Man (found in a peat bog at Lindow Moss, near Manchester, in 1985) probably died as a result of Druid sacrifice, as mistletoe, a common component of sacrifices at the time, was found in his stomach.[5] Other more scientifically advanced tests allowing the identification of biomolecules, which survive in bone for long periods, have permitted the examination of important indicators of health such as calcium, strontium and phosphorus. Equally impressive is palaeodiet analysis using stable isotope analysis of bone collagen. However, as collagen is altered by the diagenetic reactions of hydrolysis, decarboxylation and deamination, the recent development of stable carbon and nitrogen isotope analysis using hair been important.[15] This latter method has provided conclusive information that the previously mentioned Innsbruck Iceman ate a solely vegetarian diet. Finally, carbon dating has been a useful development and most human remains and their associated pathology can now be dated with a high level of certainty.

Tests to measure and interpret antibodies, antigens[5] and even the DNA of ancient individuals, made possible by developments in immunogenetics, will undoubtedly become the most important palaeopathological methods. Currently many diseases can be detected by these tests and more will be possible in the future. Therefore, obtaining HLA antigens from ancient remains can offer quality information on genetic predisposition to conditions such as rheumatoid arthritis (HLA DR4 and DR1; in Israeli Jews and Indian and Spanish populations),[16] Sjögren's syndrome (HLA DR3),[17] ankylosing spondylitis (HLA B27)[4] and Behçets syndrome (HLA B5 (51)).[18] The location where the materials were found could also be analysed by geologists, palaeobotanists and palaeodieticians for likely causes of these poorly treatable diseases. Although chromosomal abnormalities have been identified in DNA extracted from human bones 7400 years old, it is likely that non-human DNA will be most useful as it will help to identify the relative importance of malaria, cholera and the plague in ancient communities.[4] Indeed, DNA analysis of bone and soft tissue samples from eighty five ancient Egyptian mummies has shown that *Mycobacterium tuberculosis*, which causes the common human form of tuberculosis, originated from *Mycobacterium africanum* and not *Mycobacterium bovis* as previously thought.[19] This has considerable consequences for beliefs surrounding the disease and our knowledge of the health and lifestyle of ancient humans.

However, several drawbacks have prevented these new biochemical tests reaching their full potential. The major problem is that the human remains are easily contaminated with flora and fauna from their environment as well as by contemporary human handling in the field or laboratory. Some experiments have shown that authentic DNA from soft tissue remains can be obtained, but suspicions remain. The cost of these tests also means that it is unlikely that all remains from an archaeological site could be examined. Furthermore, acquiring funding may prove the most difficult obstacle. For instance, in the case of sampling the DNA of the plague bacillus, how would the skeletons be selected for study? It would be too expensive to sample all remains found and if plague pits were used as the source then one has already assumed the likely diagnosis before conducting expensive research that may not provide new information.[4]

CONCLUSION

To conclude, various methods can be employed to examine human remains. At first, palaeopathological studies depended on macroscopic examinations and autopsies, but then other forms of analyses were adopted shortly after their development or use in other branches of medicine. Consequently, the use of epidemiology, serology, biochemistry, immunogenetics and radiology has altered the scope of palaeopathology from its original tracing of illness in the remains of individual skeletons to the study of the natural environment, genetic make-up and diseases of whole societies and populations. Thus previous research can be corrected and poorly researched areas, such as rheumatoid arthritis and osteoporosis and the differences in the health of our urban and rural ancestors, can be investigated. This hopefully will promote better understanding and awareness of the work of palaeopathologists, who in addition to contributing to the understanding of the medicine and health of previous generations and societies, will hopefully provide answers for some of the medical questions of our time.

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